

Valve for a Hydraulic Drive Apparatus**CROSS-REFERENCE TO RELATED APPLICATION**

- 5 This application is a continuation-in-part of U.S. Application No. 10/664,633 filed September 18, 2003. This application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

This invention relates generally to valves, and more particularly, to a valve used
10 in hydraulic pumps and motors to improve the performance thereof. Some hydraulic
drive systems such as those used in vehicles are very efficient and such efficiency can
cause design and operation problems. For example, the hydraulic drive system may be
efficient to the point where the vehicle jerks as it begins to move, and such motion may
cause the front end of the vehicle to briefly leave the ground. Such jerks are undesirable
15 as they can cause operator discomfort and may also cause undesirable pressure shocks
within the components of the drive system that can affect the life of its components. A
variety of techniques are used to reduce the effects of that efficiency, such as use of
bleeds or kidney configurations. However, these techniques create problems of their
own, such as loss of efficiency at higher load levels.

20 **Summary of the Invention**

A valve configuration for slowing the pressure rise rate of a hydraulic drive
system during initial acceleration is disclosed herein. The disclosed valve configuration
resolves the above difficulties and adds flexibility to the placement of valves for a slow
pressure rise rate. The use of such valves in a zero turn vehicle to improve performance
25 of a pair of drive systems is also disclosed herein.

Other benefits and objects of this invention are disclosed herein and will be obvious to readers of ordinary skill in the art. The features disclosed herein can be combined to create a unique design; it should be understood, however, that such features are unique in their own right and can be used independently with other transmission, 5 transaxle or vehicle designs, as will be obvious to one of ordinary skill in the art.

Brief Description of the Drawings

Fig. 1 depicts a plan view of an exemplary vehicle with a first embodiment of a hydraulic drive system incorporating the invention.

Fig. 2 is a partially schematic plan view of a portion of the exemplary vehicle 10 shown in Fig. 1.

Fig. 3 is a side elevational view of the valve block shown in accordance with the first embodiment of this invention.

Fig. 4 is a cross-sectional plan view of the valve block shown in Fig. 3 along the lines 4-4.

Fig. 5 is an elevational view of one of the valves and the valve seat as shown in Fig. 4.

Fig. 6 is a cross-sectional view of the valve and valve seat along lines 6-6 in Fig. 5.

Fig. 7 depicts a plan view of an exemplary vehicle with a second embodiment of a 20 hydraulic drive system incorporating the invention.

Fig. 8 is a partially schematic plan view of a portion of the vehicle shown in Fig. 7, with optional porting depicted.

Fig. 9 is a side elevational view of a valve block in accordance with a second embodiment of this invention.

Fig. 10 is a cross-sectional plan view of the valve block shown in Fig. 9 along the lines 10-10.

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Detailed Description of the Drawings

Turning now to the figures, wherein like reference numerals refer to like elements, there is generally illustrated in Figs. 1 and 2 a vehicle 10 with a hydraulic drive system 12. Drive system 12 comprises a pair of hydraulic pumps 14, which are hydraulically linked to respective hydraulic wheel motors 16 by means of hydraulic lines 18. Pumps 14 obtain hydraulic fluid from a reservoir 20. Pumps 14 and motors 16 may have return lines 22 to return excess hydraulic fluid to reservoir 20 for cooling and filtration prior to being reintroduced to pumps 14.

Pumps 14 are driven by prime mover 24, which may be directly connected to pumps 14 or may be connected via one or more belts 26. Belt 26 is connected to pumps 14 by means of input pulleys 28, which are further connected to input shafts 30, which then drive hydraulic pumps 14. Wheel motors 16 drive output shafts 32, which may also function as axle shafts 32 that then drive wheels 34.

Vehicle 10 may be a variety of configurations such as a zero turn mower or the like, and vehicle 10 may include features such as mowing deck 36 mounted on frame 38. In order to steer such a vehicle, the amount of hydraulic fluid flowing between pumps 14 and motors 16 is independently adjusted to cause one side of vehicle 10 to move faster or slower. The relative speed difference between the right pump 14 and motor 16 and the

left pump 14 and motor 16 causes vehicle 10 to be steered. The ability to move the two drive units in opposite directions at the same time provides the unit zero turn capability.

In order to reduce the efficiency of drive system 12 at initial acceleration, while providing maximum efficiency during travel, a pair of valve blocks 40 are provided. As shown most clearly in **Fig. 4**, valve block 40 comprises two valves 41 and 42 mounted therein in ports 46 and 44, respectively. In **Fig. 4**, valve 41 is shown in the open position while valve 42 is shown in the closed position.

Ports 48A and 52A are both connected to pump 14 through hydraulic lines 18. Fluid pressure into port 48A from pump 14 corresponds to fluid flow in the forward direction, while fluid pressure into port 52A corresponds to fluid flow in the reverse direction.

Port 48A connects to port passage 48B, which then connects to port 48C. Additional hydraulic lines 18 are connected to port 48C to connect block 40 to a motor 16. Similarly, port 52A connects to passage 52B, which then connects to port 52C, and then by way of hydraulic lines 18 to motor 16. The hydraulic lines 18 and return lines 22 are all preferably standard rubber hoses or hard plumbing of a type sufficient to withstand the pressures presented by the hydraulic application being used.

When port passage 48B is pressurized, such as would occur during actuation of drive system 12 in the forward direction, port passage 52B in block 40 is in a low pressure condition, which may be vacuum pressure or pressure lower than atmospheric pressure.

A first opening 50 is formed by the intersection of port 46 and passage 52B. A second opening 54 is formed by the intersection of port 44 and passage 48B. Note that

openings 50 and 54 are formed by the intersection of two circular passages. There are other techniques for forming a connection between these passages that are known in the art, such as a separate machining to form these openings or casting an interconnecting passage that may open external to valve block 40 and require a separate plug to close the

5 external opening.

Port 46 is formed in block 40 such that it intersects with passage 48B, and a first valve 41 is installed in port 46. Under certain pressure conditions, valve 41 will open such that hydraulic fluid will flow from port passage 48B into port 46, where it will flow into port passage 52B by way of opening 50. The pressure differential between port 10 passage 48B and port passage 52B will cause hydraulic fluid to flow readily from passage 48B to passage 52B when valve 41 is open.

When passage 52B is under high pressure, passage 48B is at a lower pressure, which may be a vacuum pressure or a pressure lower than atmospheric pressure. Valve 42 is positioned in port 44, which intersects port passage 52B. As in the other direction, 15 when valve 42 opens, fluid will flow from port 44 to passage 48B by way of opening 54.

As is evident from Figs. 3 and 4 and from the above description, ports 48A, 48C and 46, passage 48B, and valve 41 have central axes that are generally in a first plane. Ports 52A, 52C and 44, passage 52B and valve 42 have central axes that are generally in a second plane that is different from, though preferably parallel to, the first plane. Such 20 planar separation is required so that flow through passages 48B and 52B is generally unimpeded. As noted previously, while the planes in which these features are located are separated, certain passages are located such that they intersect so as to form connecting passages 50 and 54.

Valve 41, which is preferably identical to valve 42, is shown in more detail in Figs. 5 and 6, and comprises a valve body 60 which is secured in port 46. O-ring 62 prevents leakage of oil from the interface between valve 41 and block 40. Spring 64 is mounted in bore 66 of valve body 60, and engages outer plunger cylinder 68. A center 5 piston 78, which has an inner bore 80, is mounted in inner bore 72 of outer cylinder 68. Ball 70 is pressed into inner bore 72 at one end thereof.

A separate seat 74, which is also depicted in Figs. 4 and 5, is pressed into hydraulic port 46 to a measured depth, or to a stop formed therein, and includes an opening 76 formed therein. Seat 74 could also be integrally formed with block 40. Ball 10 70 could be replaced by other shapes or a functionally equivalent feature could be integrally formed in outer cylinder 68.

Valve 41 is shown in the closed position in Figs. 5 and 6. As the oil pressure outside seat 74 increases, oil will flow through seat opening 76 into bore 80 of piston 78. The force of piston 78 against ball 70 will move cylinder 68 in a direction away from seat 15 74, thus compressing spring 64 and opening valve 41 to permit high pressure oil to pass into opening 50 as previously described. Oil will also pass through bleed orifice 84 to area 82 adjacent to ball 70 inside bore 72. As the oil pressure in area 82 increases, it increases pressure on piston 78, forcing piston 78 to move axially away from ball 70 to the point where it again engages seat 74 and closes valve 41.

20 The rate at which valve 41 opens and closes may be set by design choices such as the spring constant of spring 64 and the diameters of inner bore 80 and bleed orifice 84. Therefore, when the pressure in passage 48B is sufficiently high, such as at engagement of the drive system and initial vehicle movement when the pressure would spike, valve

41 acts to relieve or dampen this pressure spike and improve the ride and performance of the vehicle. Similarly, valve 42 acts in the same manner when pump 14 is put into reverse to dampen any pressure spike in port passage 52B. In the embodiment shown in Fig. 2, both blocks 40 would operate in the same manner to provide damping for both 5 pumps 14.

In some vehicle designs, only the forward or reverse direction may need the pressure rise rate controlled; in such a case either valve port 44 or valve port 46 may be eliminated and valve block 40 would include only a single valve.

A second embodiment of this invention is shown in Figs. 7-10; in this 10 embodiment certain features are identical to those previously described herein and are given identical numerals. As shown in Fig. 7, hydraulic drive system 112 includes valve blocks 140 which are not in line between pump 14 and motor 16 but rather are offset and are connected to the main lines 118 through tee fittings 21. This configuration allows for a less complex design for valve block 140, resulting in less machining required and 15 consequently lower cost. Allowing valve block 140 to be offset from pump 14 and motor 16 enables the user to mount valve block 140 in a wide range of locations in vehicle 110.

A cross-sectional view of block 140 is shown in Fig. 10. Valves 141 and 142 can be identical in construction to valves 41 and 42 discussed previously. Block 140 comprises two inlets 86 and 87 connected to separate ports 91 and 93, respectively. A 20 single outlet 88 is connected to an outlet port 85 which intersects both inlet ports 91 and 93. As before, one of the inlet ports is connected to each of the pump main lines 118 through tee fittings 21, so each one corresponds to either the forward or the reverse side of the hydraulic circuit. In Fig. 10, valve 141 is shown as closed and valve 142 is shown

in the open position, such that hydraulic fluid can be diverted from the hoses 118 to outlet 88.

Fig. 8 shows two alternative connections of outlet hose 23; it can extend from outlet 88 through hose 23b where it will go to the charge gallery of each pump 14. As an alternative, the system could be setup so that hydraulic fluid returns through hose 23a to reservoir 20. This option can be given to the person assembling the unit, and the choice of outlet flow paths will depend on factors such as the size of the charge pump (not shown) used with pump 14. If the charge pump is large enough, the fluid can be sent to reservoir 14 for additional cooling. A smaller charge pump may require fluid to be returned to the charge gallery.

While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangement disclosed is meant to be illustrative only and not limiting as to the scope of the invention which is to be given the full breadth of the appended claims and any equivalents thereof.